

Effect of Improper Valve Setting
On the Economy of a
Simple Corliss Engine

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THE EFFECT OF IMPROPER VALVE SETTING
ON THE ECONOMY OF A SIMPLE
CORLISS ENGINE

A THESIS

PRESENTED BY

Theodore Wachs
Clarence Earle Kilgore
Malcolm S. MacDonald

TO THE

PRESIDENT AND FACULTY

OF

ARMOUR INSTITUTE OF TECHNOLOGY

FOR THE DEGREE OF

BACHELOR OF SCIENCE IN MECHANICAL ENGINEERING

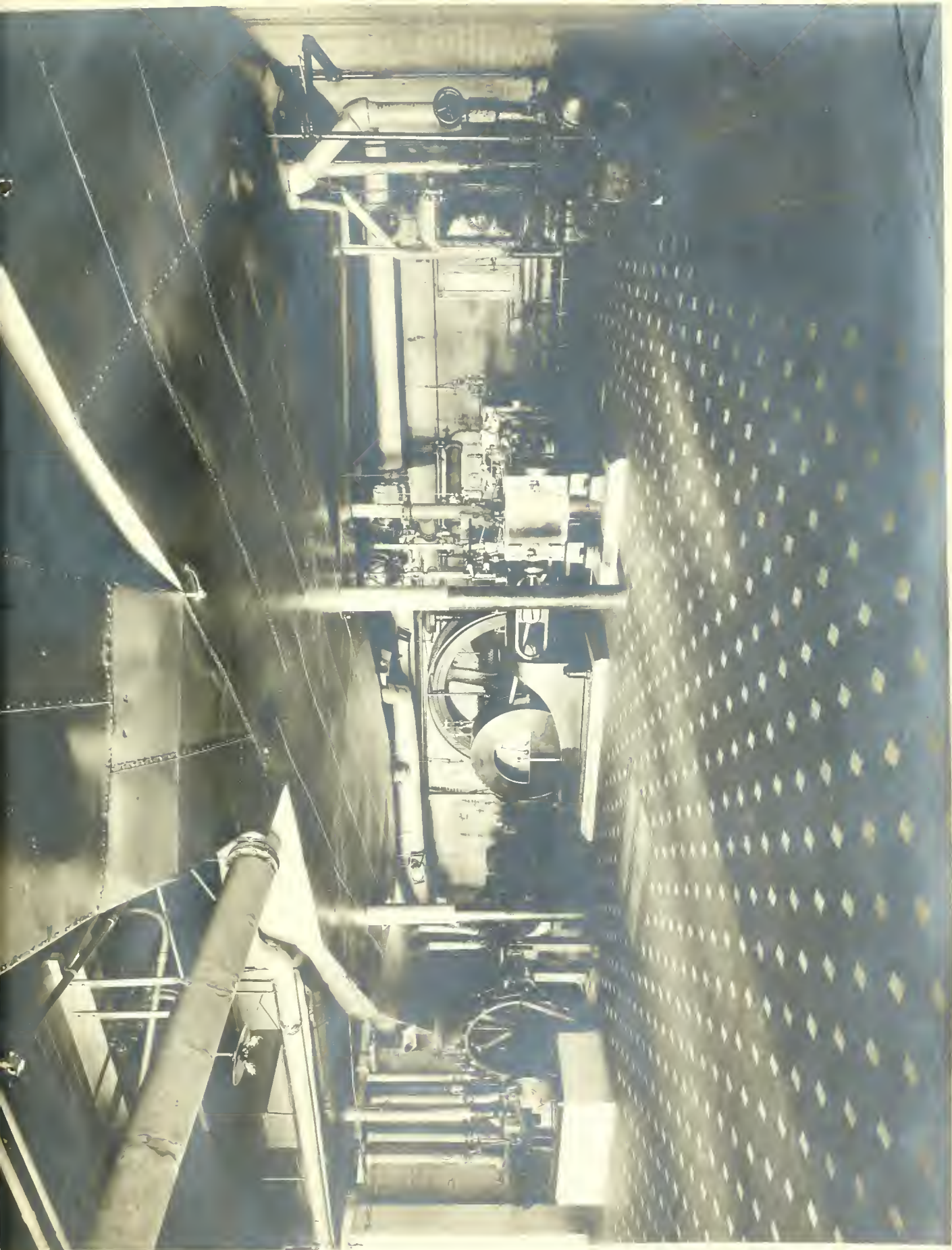
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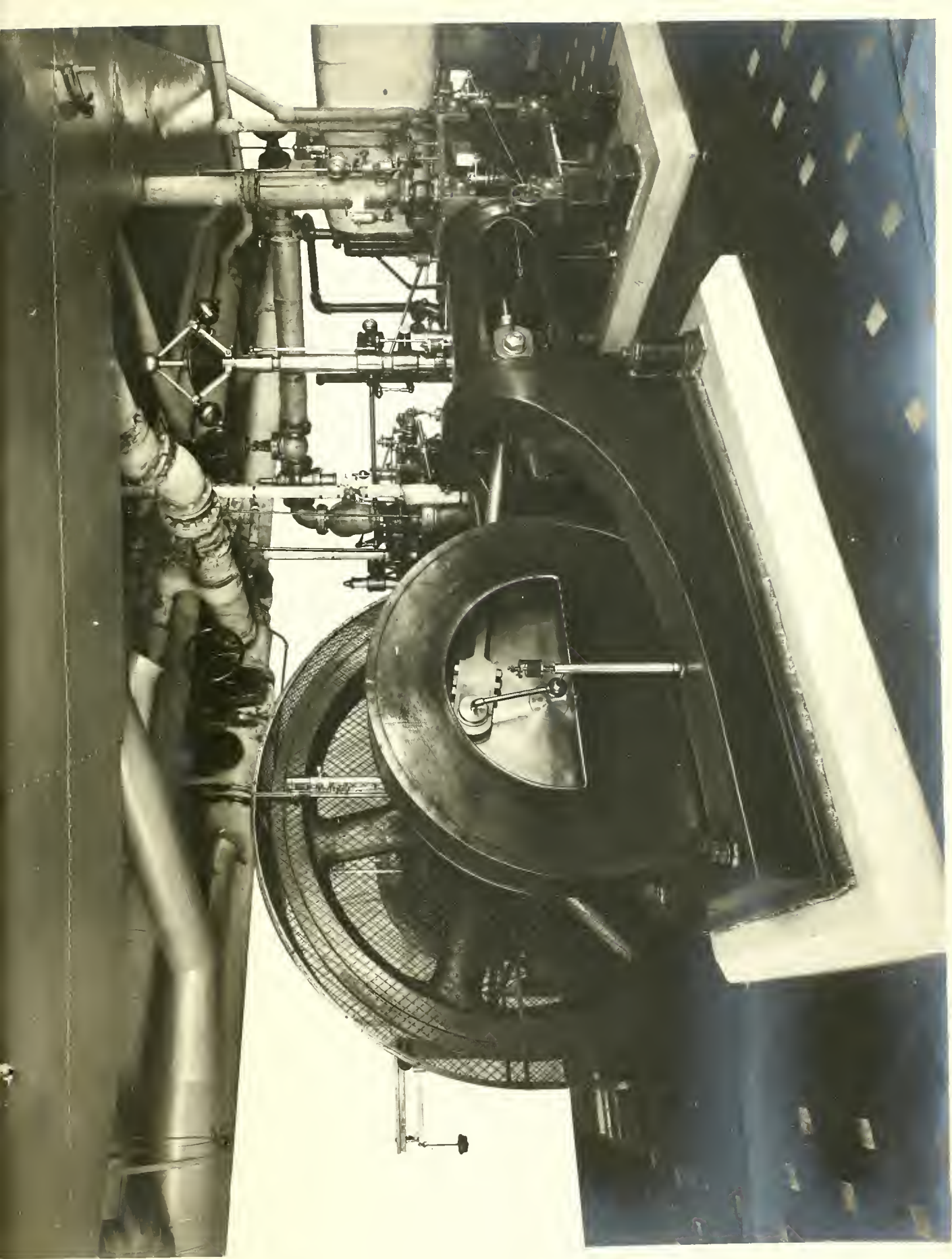
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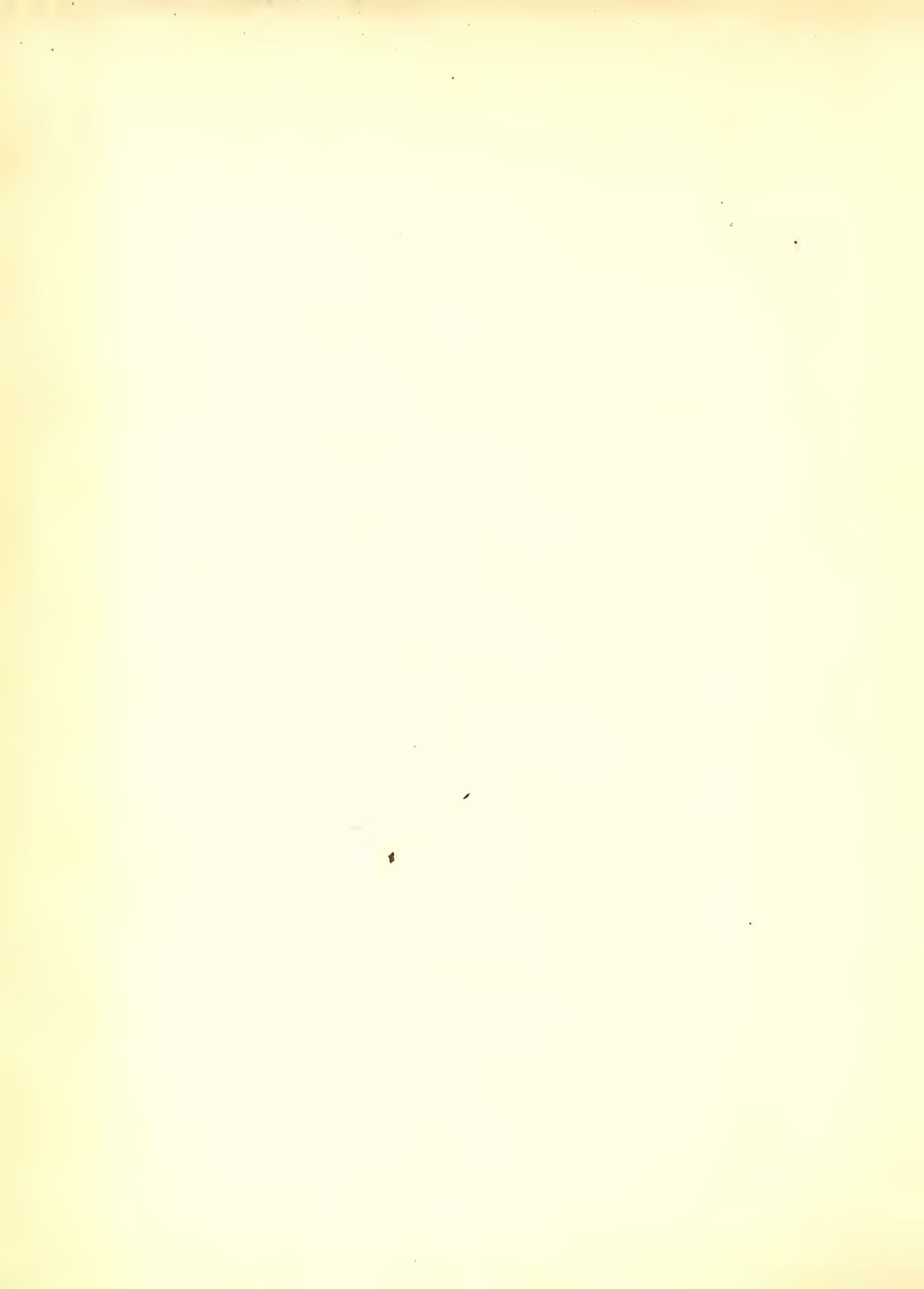
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THE EFFECT OF IMPROPER VALVE SETTING ON THE ECONOMY
OF A SIMPLE CORLISS ENGINE.

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OBJECT.

The introduction of the Corliss Engine in 1849 marked the beginning of a new era in steam engine practice. Previous to its appearance there was a widespread demand for an engine of greater economy and closer regulation. When the new engine was invented its possibilities were quickly noted. Its evolution since that time has been so remarkable that today it stands as the most universal type of reciprocating engine. Its most radical departure from the existing engines, and in fact, the feature to which it owes its better economy, is found in the operation and control of the cylinder steam events.

There is some definite arrangement of the sequence of the cylinder events of a Corliss engine for maximum steam economy. A departure from the proper time of occurrence of any one of these affects the economy of the engine. The conditions of operation of an engine are subject to such great variations and are so unique for each installation, that the events must be capable of adjustment between certain limits. This adjustment permits of a "setting" to suit the existing conditions.

With these considerations in mind, the principal object of this thesis became the determination of the effect

of improper valve setting on the economy of a simple Corliss engine. Incidental to this was the securing of a series of indicator cards showing graphically the changes made in the settings.

APPARATUS USED.

The apparatus used in this thesis consisted of the high pressure cylinder of the 9" & 18" x 24" Cross Compound Allis-Chalmers Experimental Corliss Engine located at The Armour Institute of Technology. Both the high and the low pressure cylinders of this engine are equipped with double plated valve gears. For the purpose of this thesis the low pressure connecting rod and the low pressure eccentric rods were dropped so that the engine would run on the high pressure cylinder alone.

The valves in the connection between the high and low pressure cylinders were so set that the exhaust steam passed directly into the exhaust line without entering the receiver or low pressure cylinder.

The Wheeler Surface Condenser, having 423 sq. ft. of cooling surface, and its Knowles patent wet air pump, were used for condensing the steam and discharging the condensation to the weighing tanks.

Two weighing tanks, each located on scales, were used for the determination of the amount of steam required by the engine.

The engine was fitted with a water-cooled Prony Brake

for the absorption of the power developed, which was measured by scales.

Two Crosby indicators were used for the determination of the indicated horse power. The motion of the crosshead was conveyed to the indicators by cords attached to a pantagraph.

For determining the quality of the steam, a superheating calorimeter was located in the steam lead to the engine. This calorimeter was supplied with a 400° F. thermometer.

A test pressure gauge was used for reading the steam pressure on the engine. A mercury column attached directly to the condenser gave the vacuum in inches of mercury.

The constants of the engine used are as follows:

Diameter of cylinder - - - - - 9 in.

Stroke - - - - - 24 in.

Diameter of piston rod - - - 1-7/8 in.

Area of piston, head end, - - 63.617 sq. in.

Area of piston, crank end, -- 60.856 sq. in.

Piston displacement, head end- 0.884 cu. ft.

Piston displacement, crank " - 0.845 cu. ft.

Clearance volume, head end - -11.1% of piston displacement.

Clearance volume, crank end - 11.4% of piston displacement.

CALIBRATION OF INSTRUMENTS AND APPARATUS.

At the start of the thesis work the steam gauge used was checked up on a Crosby Gauge Tester, and set to read correctly at 100 lbs., at which pressure the runs were made.

Three times during the thesis work this gauge was checked to the same pressure and found to be correct.

The indicator springs, nominally 80 lbs. each, were calibrated at the beginning, again about the middle, and a third time at the completion of the work. The calibrations showed that during the experiments no appreciable change had taken place in the scale of the springs. The scale of the head end spring was 90.4 lbs., and the scale of the crank end spring was 88 lbs.

At the beginning of each day's work the zero of the mercury column scale was adjusted to the level of the mercury in the bath below the tube.

The brake constants were determined in the most accurate manner possible under the existing conditions. There were two notches in the brake arm: the outer $41\frac{3}{4}$ ", and the inner $40\text{-}5/8$ " from the center of the shaft. As the inner notch was the larger, that was used, and the determination of the dead load of brake was made with it.

The tension was removed so that the brake hung loose on its wheel. The engine was then turned over and machine oil poured onto the wheel until the friction was reduced to a minimum. Then, with a pair of spring balances, the brake arm was raised at a uniform rate of speed. By numerous trials the reading on the scale was found to be 44 lbs. The arm was then lowered at the same rate at which it had been raised, and the scale reading again noted.

This reading was 22 lbs. The average of these readings, 33 lbs., was taken as the dead load of the brake. The weight of the strut was $7\frac{1}{2}$ lbs., making a total dead load of $40\frac{1}{2}$ lbs. for the brake arm and strut. This determination was checked in the following manner: the scales were set at $40\frac{1}{2}$ lbs; the brake arm was lifted about 6 inches above the strut, and allowed to drop, falling on the inner notch. This just balanced the scales.

METHOD OF CONDUCTING RUNS.

As the principal object of this thesis was the determination of the water rate of the engine with different valve settings, it was necessary to adopt a uniform basis of conducting the runs, so that direct comparisons could be made.

Since 100 lbs. gauge pressure is common practice, this pressure was used throughout the thesis work; and as 26" of mercury is the vacuum usually employed in connection with reciprocating steam engines, the condensing runs were made with this vacuum. When running non-condensing, the pressure at the condenser was atmospheric.

It was anticipated that considerable variation in cut-off would be necessary to make up for the lost portions of card area, and therefore several preliminary runs were made to determine the maximum automatic cut-off of the engine. For conducting the runs a gross brake load of 550 lbs. was adopted, which brought the cut-off well inside the maximum limit.

It was our intention to conduct all runs with this brake load, and as will be seen later, this was satisfactory for all runs but one. A gross brake load of 550 lbs. gave a net brake load of $509\frac{1}{2}$ lbs.

It was necessary to have a standard of reference as a basis of comparison. The setting of the valves of the engine as shown on the manufacturers' drawings was adopted as being normal or ideal. Subsequent tests showed that this setting gave the minimum water rate.

Half-hour runs were considered to be of sufficient length to give consistent results.

Since it was not possible to obtain the desired range of conditions by an alteration of the valve rod length, it was decided to vary the valve setting by shifting the eccentrics. Trial showed that 10° gave a sufficient change, and therefore 10° intervals were laid off on the eccentric and on the shaft, both ahead and behind the normal setting.

In its turn each eccentric was held constant while the other was varied by these 10° increments, and a condensing and a non-condensing run was made with each setting.

During the runs no effort was made to equalize the events of the two ends of the cylinder, and the difference of the position of events which appears on the indicator cards was due to the angularity of the valve rods.

Twelve indicator cards were taken from each end of the cylinder during every run, and at the same time readings were taken of the temperature in the steam calorimeter, of

the speed of the engine, and of the vacuum, in the case of the condensing runs. As stated previously, the steam pressure was maintained at 100 lbs. gauge.

By an occasional manipulation of the pump speed and amount of cooling water, the vacuum was easily maintained at 26 inches.

Slight variations in pressure occurred, since it was necessary to go to the shut-off valve at the steam main to regulate the steam pressure. However, these variations were not sufficient to introduce any appreciable error in the results.

RUNS MADE.

The first run made was with the normal setting of the valves. The condensing run was called No. 1, and the non-condensing run was called No. 2. Throughout the experiments the odd numbers represent the condensing runs, and the even numbers following them, the corresponding non-condensing runs.

After the completion of the runs with normal valve setting, the steam eccentric was shifted 10° forward, causing earlier admission. Runs were made under this condition. Two more sets of runs were made with further increases of angular advance on the steam eccentric, and the steam eccentric was then swung back 10° behind normal. Two other settings were made with the steam eccentric behind normal, and condensing and non-condensing runs made for all. This

series of runs, three with early and three with late admission, completed the investigation of the variation due to change of point of admission. The steam eccentric was then returned to its normal position.

The exhaust eccentric was next shifted to four different positions ahead of its normal, which change made both compression and release later. Then the exhaust eccentric was shifted to five positions behind its normal, which change made both compression and release earlier.

With all of these varying positions of eccentrics, both condensing and non-condensing runs were made. Each run was conducted as previously outlined, the greatest care being taken in all determinations, and particularly in the determination of the steam used during the run, as this was the vital element of the work.

The only exception to the method of conducting the runs was in the case of the non-condensing run with the steam eccentric 30° ahead of normal. In this run, No. 8, it was soon apparent that the load was too great to permit the automatic cut-off to operate; so the brake load was reduced to 500 lbs. gross, or $459\frac{1}{2}$ lbs. net.

The completion of the calculations showed that the results of certain runs were not consistent. In such cases, one and sometimes two, re-runs were made as a means of verifying results or correcting errors in the original runs. The entire series of runs with increased compression were re-made, since the difference in the water rate as

indicated by the first runs was so slight that a further verification was deemed necessary.

The averages of the observations made on each setting are incorporated in Log Sheet No. 1. Reference to this sheet will show that the run number, the vacuum in inches of mercury, the revolutions per minute, the barometer in inches of mercury, the temperature in calorimeter, the quality of steam, the total weight of steam used per hour, both wet and dry, and the brake horse power have been recorded for each run. Result Sheet No. 1 shows the event being changed, and Result Sheet No. 2 shows the position of the eccentrics during the run.

1284 cards were taken and integrated. This does not include the cards taken on preliminary runs.

RESULTS.

The results obtained are to be found on Result Sheets Nos. 1, 2, and 3.

Result Sheet No. 1 presents a portion of the data obtained from the indicator cards. These data are incidental to the determination of the indicated horse power of the engine. This result sheet also makes statement of the event or events being changed, and whether the runs were condensing or non-condensing.

Result Sheet No. 2 presents a further portion of the calculated results leading up to the steam consumption per I.H.P. and B.H.P. Hours. This sheet also presents the

mechanical efficiency of the engine.

Result Sheet No. 3 shows the point of stroke at which the event being changed occurred. These data are the average of the head and crank ends and were taken from indicator cards with as much care and accuracy as possible. As anticipated, we found that these percents of stroke occurred at the same point on all cards of one run. On this sheet are also found the principal results of this thesis; namely, the difference between the steam consumption with setting under ideal conditions and the steam consumption with the setting under consideration. The percent. of variation of steam consumption from normal is also recorded.

These results are graphically presented in two series of curves. The ordinates of the first series are the dry steam per I.H.P. and B.H.P. Hours, while the abscissae are the percent. of stroke at which the event being changed occurs. For ordinates the second series of curves have the percent. of difference from normal in water rate per I.H.P. and per B.H.P. Hours, and abscissae are the same as on the first series.

The curves showing both the steam consumption and percent. of difference in water rate, are practically the same for release and compression, as these two events changed simultaneously.

The lowest point on all these curves is the point of ideal setting. From this point the increase in both directions is very marked. This is particularly so in the case

of late compression, wherein the curves assume practically a vertical line. This is due to the fact that for the last run made with late compression the steam valve opened before the exhaust valve closed, thereby permitting live steam to blow through the cylinder without performing any work.

It is interesting to know that in all the curves of steam consumption those for condensing runs are concave downward, while those for the non-condensing runs are concave upward. This shows that the water rate for the non-condensing runs increases more rapidly than the water rate for the corresponding condensing runs.

The curves showing the percent. of difference in water rate, are the most important results of this thesis, as the results they present are applicable to any Corliss Engine of approximately the same percent. of clearance volume; that is, if any of the events of an engine are distorted the percent. of loss can be found by reference to these curves.

Eight plates of indicator cards are included in this thesis. They present the cards showing early and late admission, both condensing and non-condensing; and the cards showing early and late release and compression, both condensing and non-condensing.

The cards used on these plates are the average cards of the runs as indicated by the numbers. By means of these plates, the gradual change of events is very clearly shown.

RUNNING LCG.

RUN NO.	VAC.	R.P.M.	BAR.	TEMP.	QUAL.	STEAM USED		BRAKE
	INCHES		INCHES	IN	OF	PER HOUR, LBS		HORSE
	HG.		HG.	CALOR.	STEAM	WET	DRY	POWER
1	26"	94.8	29.6"	248°	97.58%	1079	1053	31.11
3	26"	93.8	29.3"	243.7°	97.4 %	1114	1085	30.79
5	26"	93.1	29.5"	247.6°	97.65%	1154	1126	30.56
7	26"	91.	29.45"	237.8°	97.08%	1224	1187	29.87
2	0	93.7	29.6"	248.2°	97.6 %	1163	1135	30.75
4	0	93.2	29.3"	246°	97.53%	1170	1152	30.59
6	0	92.8	29.5"	246.6°	97.57%	1248	1217	30.46
8	0	90.6	29.45"	240.4°	97.2 %	1234	1199	26.81
1	26"	94.8	29.6"	248°	97.58%	1079	1053	31.11
9	26"	94.9	29.6"	246.2°	97.45%	1135	1106	31.15
11	26"	94.9	29.6"	243.2°	97.3 %	1159	1128	31.15
13	26"	94.7	29.6"	252.1°	97.8 %	1176	1150	31.09
2	0	93.7	29.6"	248.2°	97.6 %	1163	1135	30.75
10	0	93.3	29.6"	237°	96.95%	1192	1156	30.62
12	0	93.5	29.6"	245.2°	97.4 %	1202	1171	30.69
14	0	93.9	29.6"	248.6°	97.63%	1328	1296	30.82
1	26"	94.8	29.6"	248°	97.58%	1079	1053	31.11
15	26"	93.2	29.4"	242°	97.32%	1113	1083	30.59
17	25½"	93.1	29.4"	245.6°	97.5 %	1165	1136	30.56
19	26"	93.2	29.4"	249.6°	97.73%	1194	1167	30.59
21	25½"	92.5	29.4"	257.8°	98.15%	1464	1436	30.37
2	0	93.7	29.6"	248.2°	97.6 %	1163	1135	30.75
16	0	92.4	29.4"	239°	97.15%	1206	1172	30.33
18	0	92.5	29.4"	242.8°	97.35%	1225	1192	30.37
20	0	92.2	29.4"	246°	97.52%	1296	1264	30.27
22	0	91.5	29.4"	258.7°	98.21%	1585	1556	30.03
1	26"	94.8	29.6"	248°	97.58%	1079	1053	31.11
23	26"	93.9	29.4"	243.8°	97.38%	1097	1068	30.82
25	25½"	93.5	29.45"	241°	97.25%	1104	1074	30.69
27	26"	93.9	29.35"	238°	97.1 %	1129	1096	30.82
29	26"	93.3	29.35"	238.3°	97.11%	1140	1107	30.62
31	26"	93.1	29.3"	248.4°	97.76%	1157	1131	30.56
2	0	93.7	29.6"	248.2°	97.6 %	1163	1135	30.75
24	0	93.1	29.45"	240°	97.18%	1177	1144	30.56
26	0	92.75	29.45"	241°	97.25%	1184	1151	30.44
28	0	92.3	29.35"	243.7°	97.41%	1233	1201	30.30
30	0	92.	29.35"	223.7°	96.35%	1301	1254	30.20
32	0	91.2	29.6"	249.5°	97.7 %	1359	1327	29.94
NET LOAD ON SCALES				509.5*	FOR ALL RUNS BUT *8. *8-459.5*			
STEAM PRESSURE				100*	" "	" "	" "	" "
PRESSURE IN CALORIMETER				¼" HG	" "	" "	" "	" "
LENGTH OF BRAKE ARM				40 5/8"	" "	" "	" "	" "

DATA FROM CARDS.

RUN NO.	AVERAGE		INDICATED HORSE POWER			R.P.M.	EVENT BEING CHANGED	
	AREA OF CARDS HEAD	CRANK	HEAD END	CRANK END	TOTAL			
1	2.83	2.66	20.33	17.79	38.12	94.8	ADMISSION MADE EARLIER, CONDENSING.	
3	2.75	2.69	19.55	17.81	37.36	93.8		
5	2.72	2.57	19.20	16.90	36.10	93.1		
7	2.70	2.65	18.61	17.01	35.62	91.		
2	2.70	2.57	19.15	16.98	36.13	93.7	ADMISSION MADE EARLIER, NON-CONDENSING.	
4	2.67	2.55	18.83	16.80	35.63	93.2		
6	2.70	2.56	18.98	16.77	35.75	92.8		
8	2.38	2.43	16.34	15.55	31.89	90.6		
1	2.83	2.66	20.33	17.79	38.12	94.8	ADMISSION MADE LATER, CONDENSING.	
9	2.77	2.77	19.93	18.55	38.48	94.9		
11	2.61	2.75	18.78	18.45	37.23	94.9		
13	2.53	2.85	18.14	19.05	37.19	94.7		
2	2.70	2.57	19.15	16.98	36.13	93.7	ADMISSION MADE LATER, NON-CONDENSING.	
10	2.70	2.63	19.09	17.33	36.42	93.3		
12	2.60	2.69	18.42	17.75	36.17	93.5		
14	2.56	2.74	18.22	18.16	36.38	93.9		
1	2.83	2.66	20.33	17.79	38.12	94.8	COMPRESSION & RELEASE MADE LATER, CONDENSING.	
15	2.74	2.71	19.35	17.84	37.19	93.2		
17	2.67	2.63	19.84	17.29	37.13	93.1		
19	2.70	2.62	19.07	17.25	36.32	93.2		
21	2.73	2.62	19.14	17.10	36.24	92.5	COMPRESSION & RELEASE MADE LATER, NON-CONDENSING.	
2	2.70	2.57	19.15	16.98	36.13	93.7		
16	2.67	2.64	18.70	17.20	35.90	92.4		
18	2.66	2.60	18.62	16.98	35.60	92.5		
20	2.68	2.58	18.73	16.79	35.52	92.2	COMPRESSION & RELEASE MADE LATER, NON-CONDENSING.	
22	2.75	2.63	19.06	17.00	36.06	91.5		
1	2.83	2.66	20.33	17.79	38.12	94.8		COMPRESSION & RELEASE MADE EARLIER, CONDENSING.
23	2.80	2.71	19.92	17.96	37.88	93.9		
25	2.79	2.67	19.75	17.63	37.38	93.5		
27	2.76	2.69	19.62	17.83	37.45	93.9		
29	2.79	2.65	19.73	17.47	37.20	93.3	COMPRESSION & RELEASE MADE EARLIER, NON-CONDENSING.	
31	2.82	2.62	19.88	17.22	37.10	93.1		
2	2.70	2.57	19.15	16.98	36.13	93.7		
24	2.63	2.65	18.55	17.41	35.96	93.1		
26	2.63	2.65	18.49	17.38	35.87	92.75	COMPRESSION & RELEASE MADE EARLIER, NON-CONDENSING.	
28	2.75	2.69	19.23	17.52	36.75	92.3		
30	2.70	2.66	18.84	17.28	36.12	92.		
32	2.64	2.70	18.26	17.36	35.62	91.2		
SCALE OF INDICATOR SPRINGS,				HEAD END 90.4*		CRANK END 88*.		
AREA OF PISTON				" " 63.617		" " 60.856		
LENGTH OF CARDS 4.6".								
RESULT SHEET #1.								

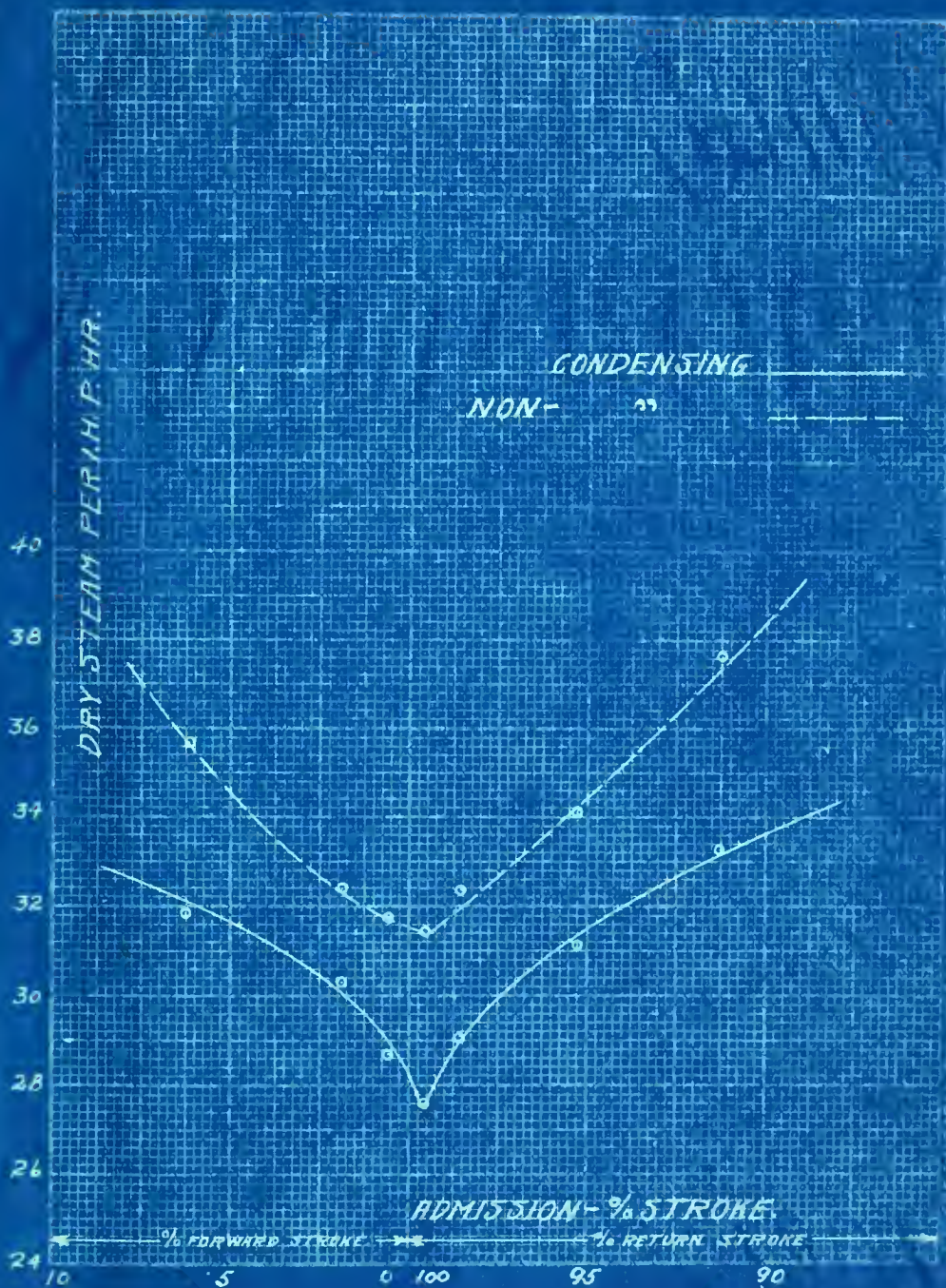
CALCULATED RESULTS.

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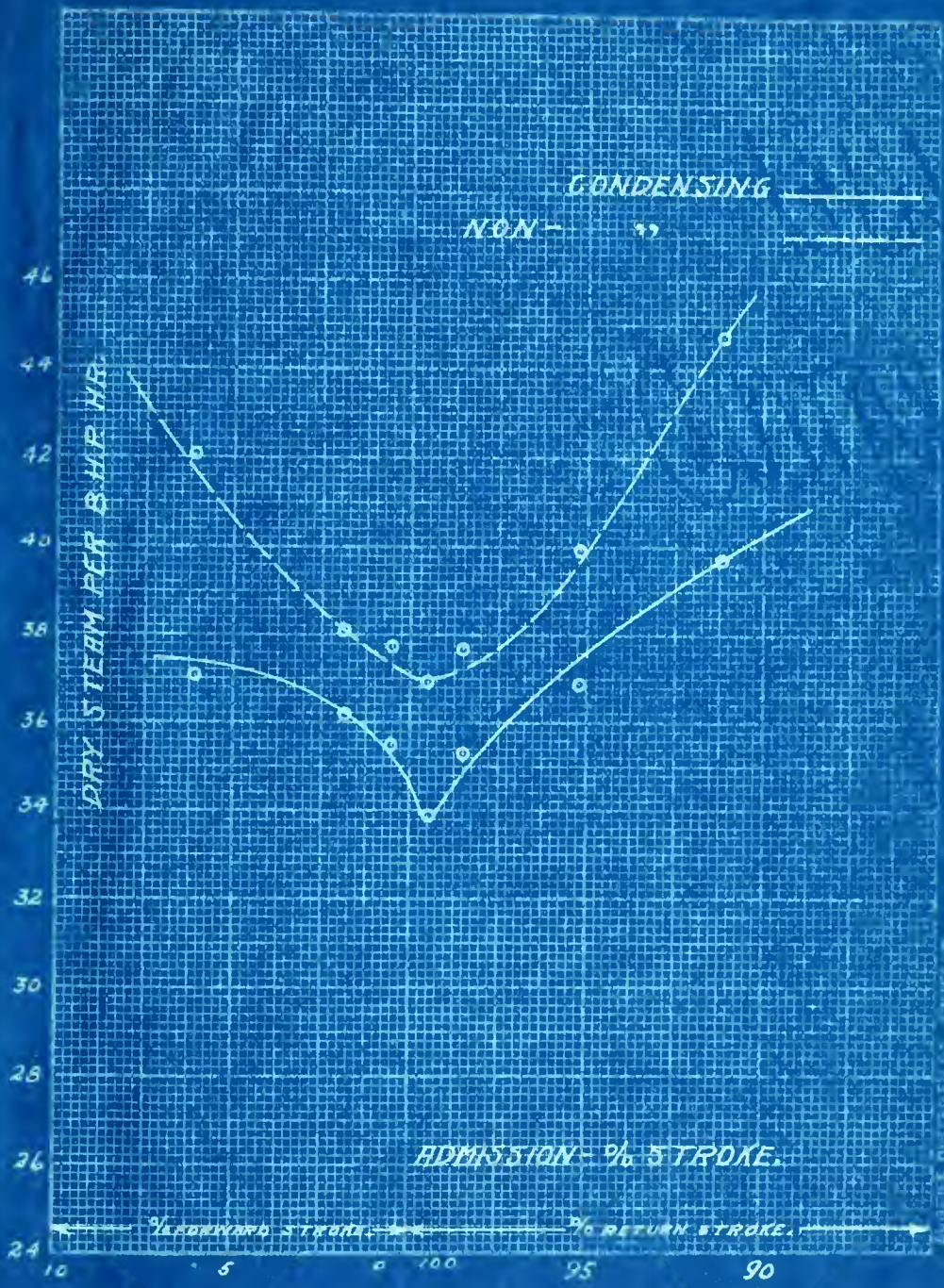
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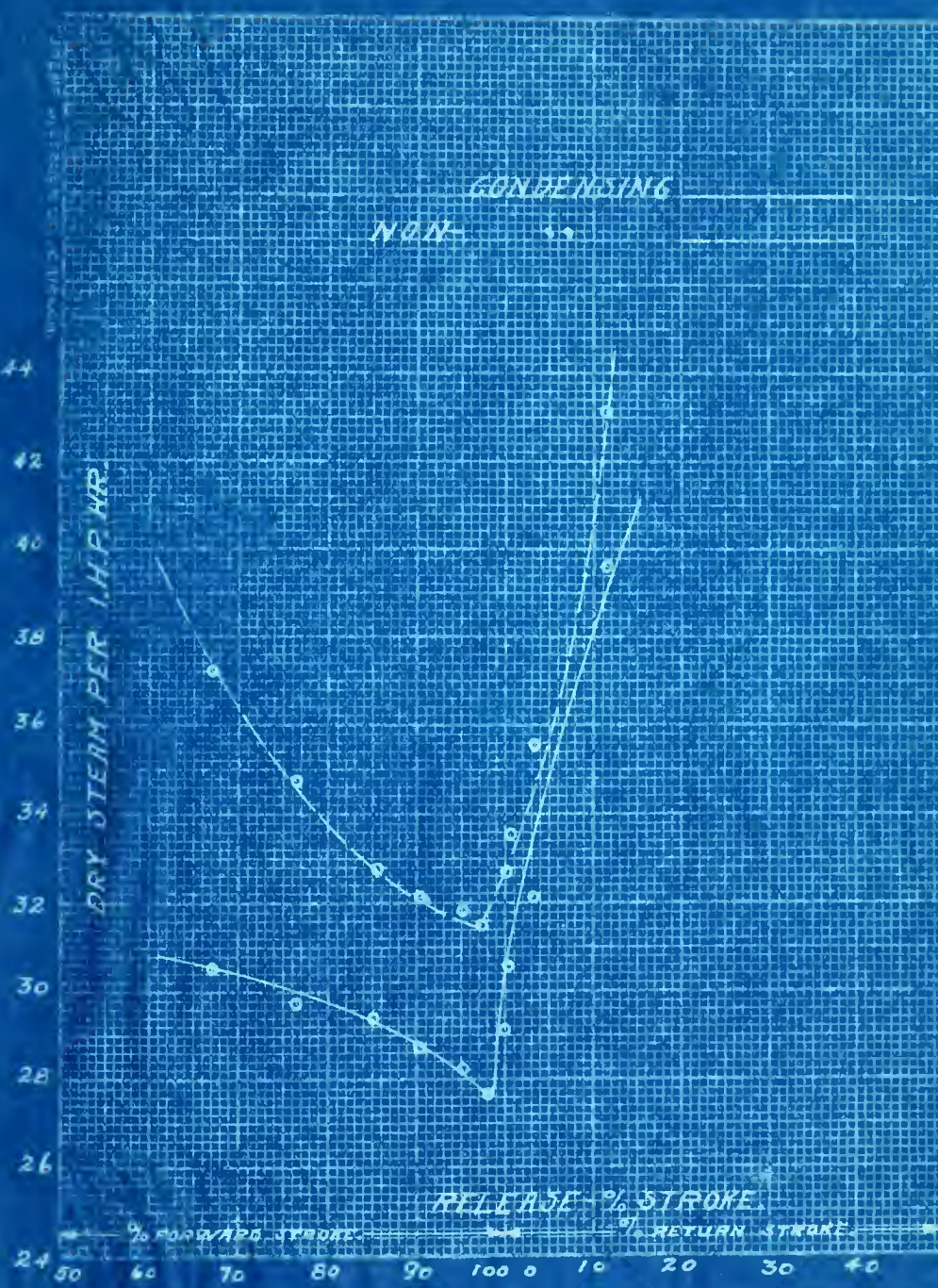
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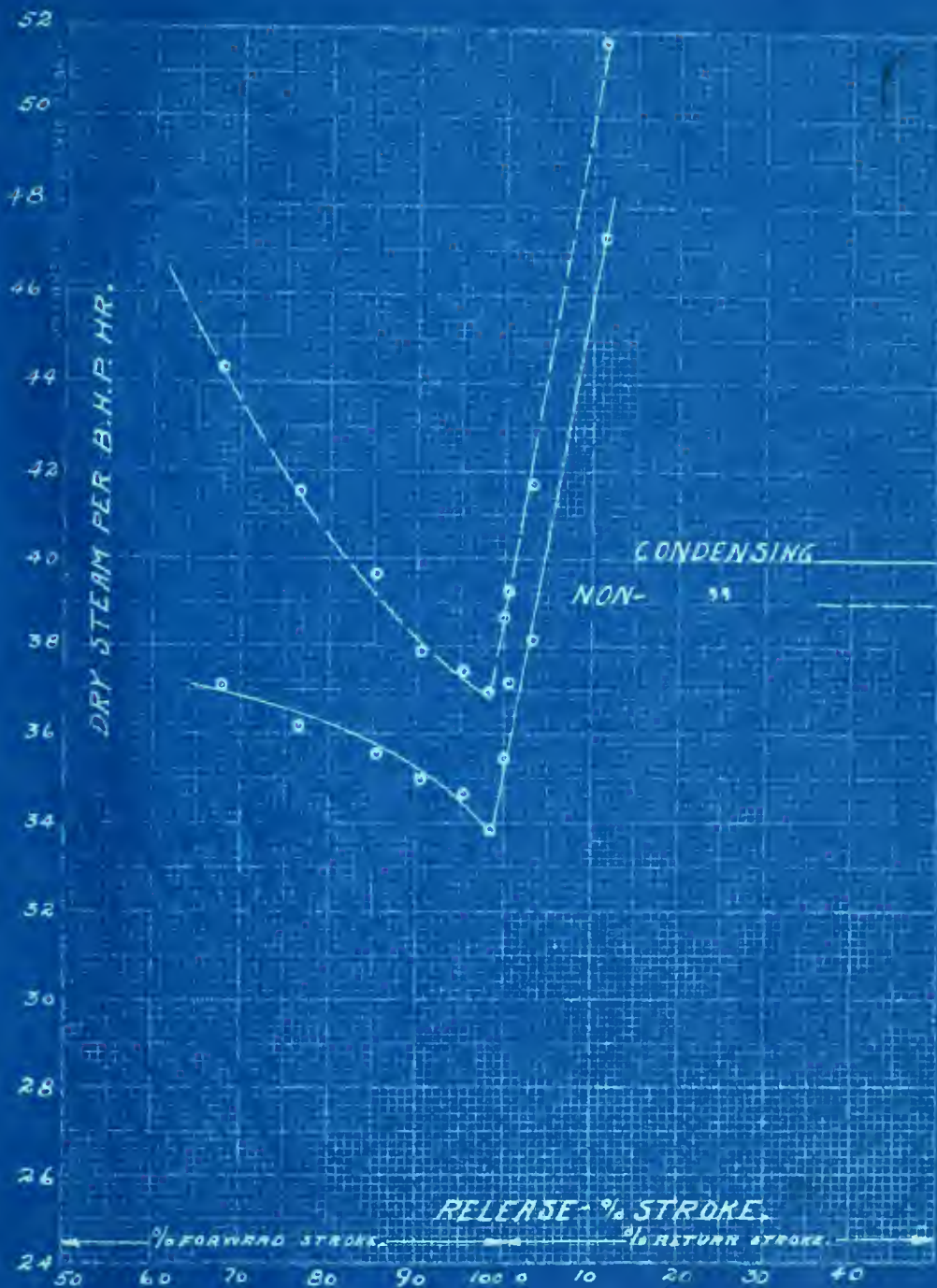


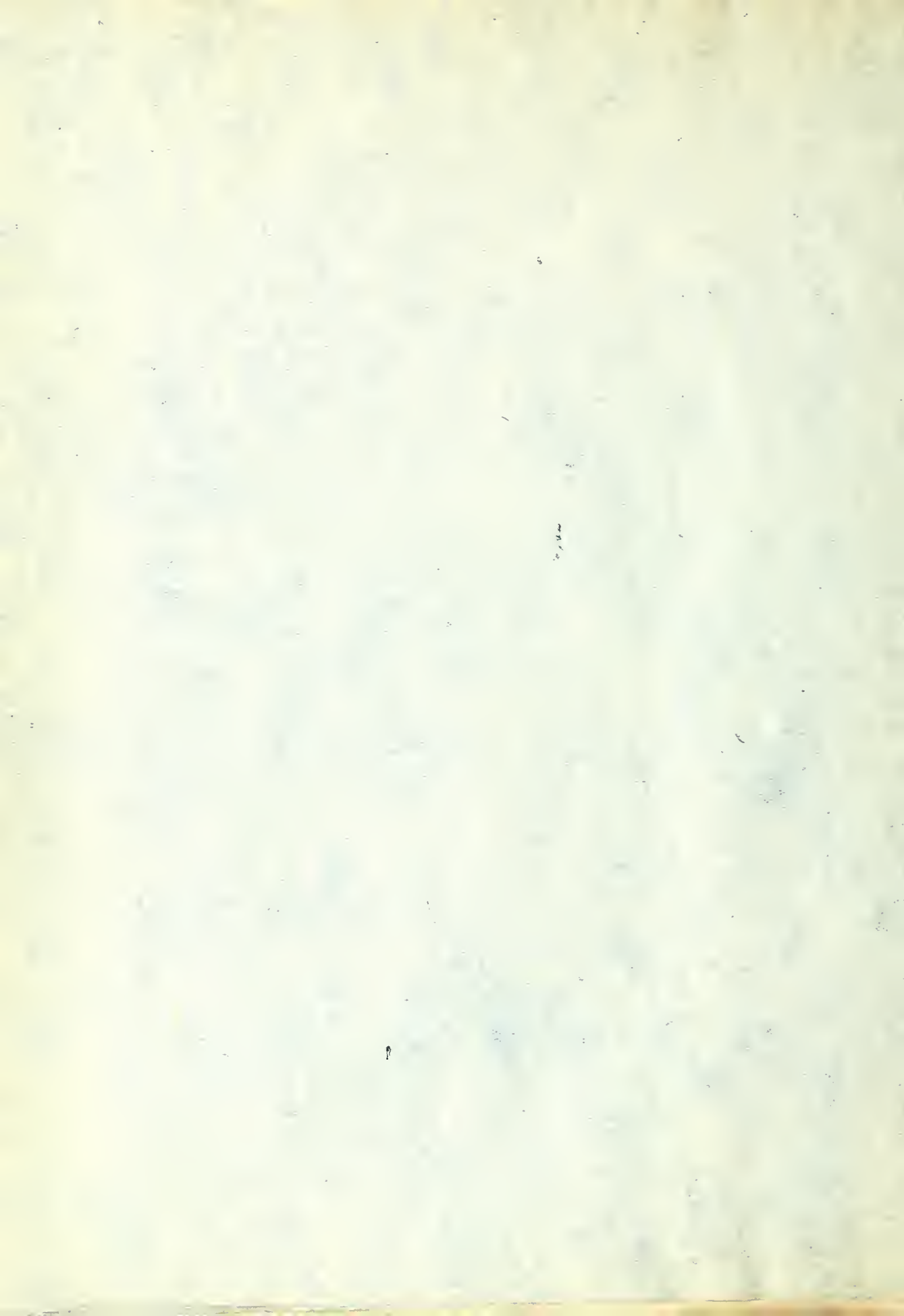


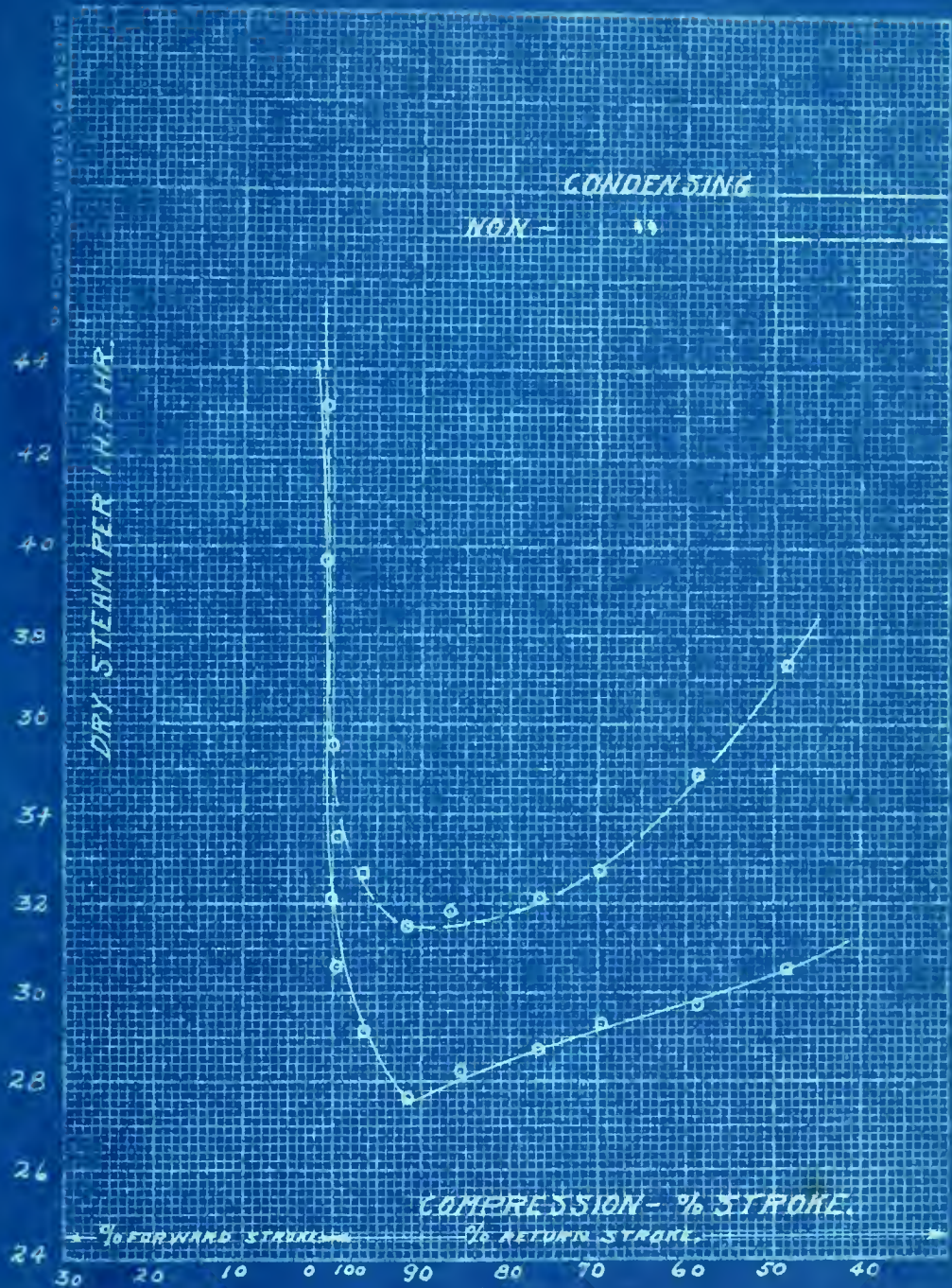


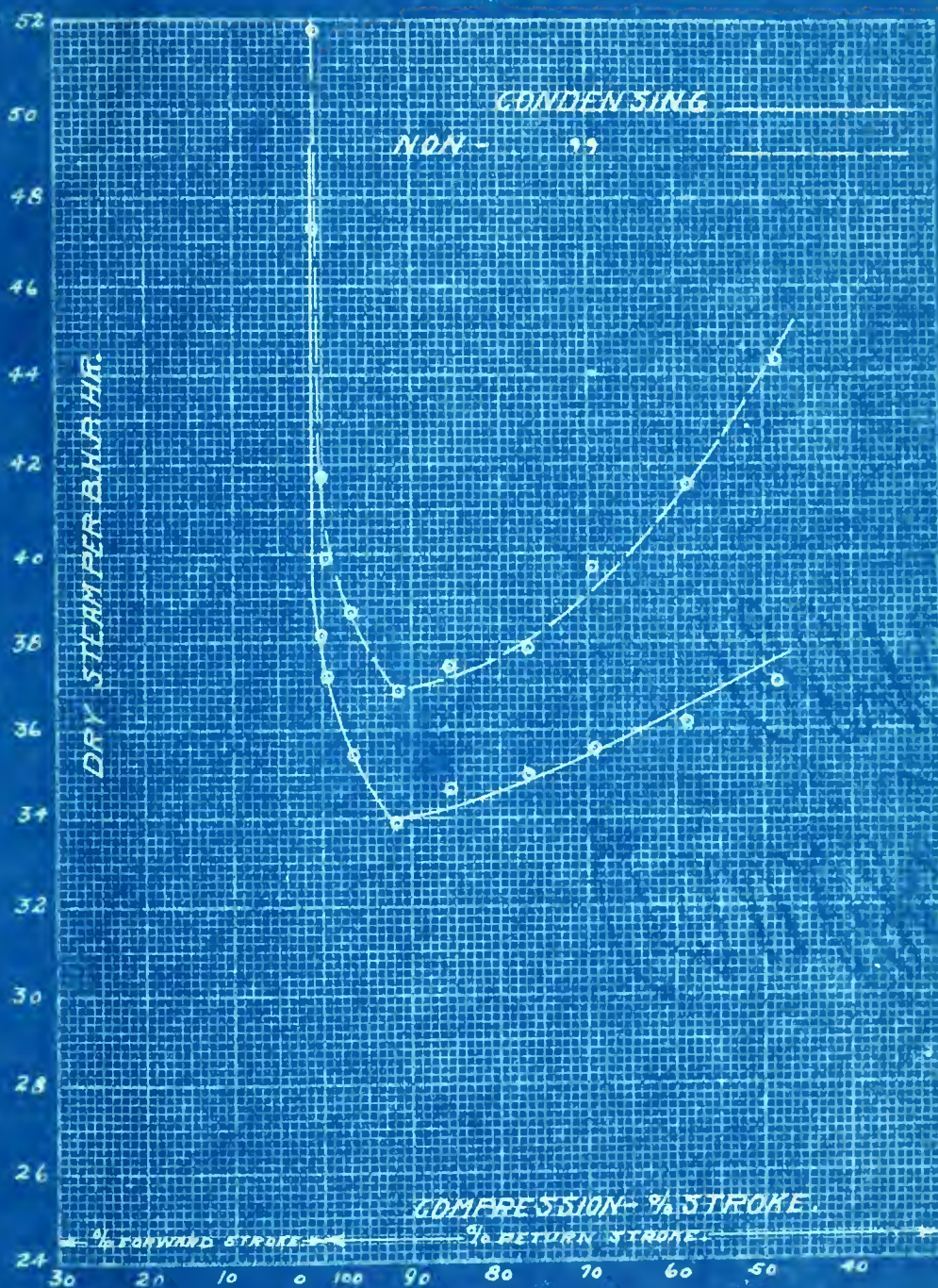










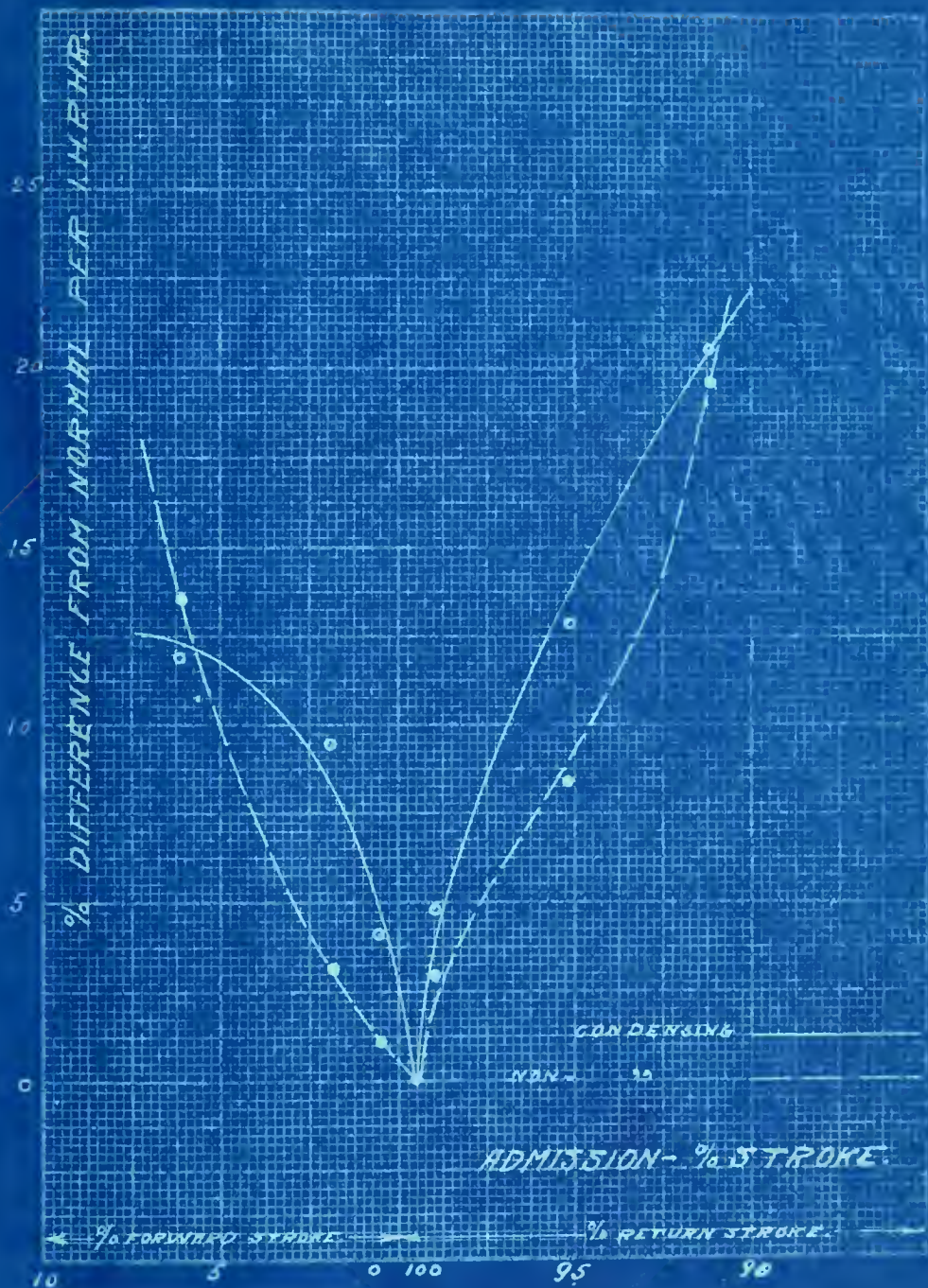


DRY STEAM PER BHP HR.

COMPRESSION - % STROKE

% FORWARD STROKE

% RETURN STROKE



25

20

15

10

5

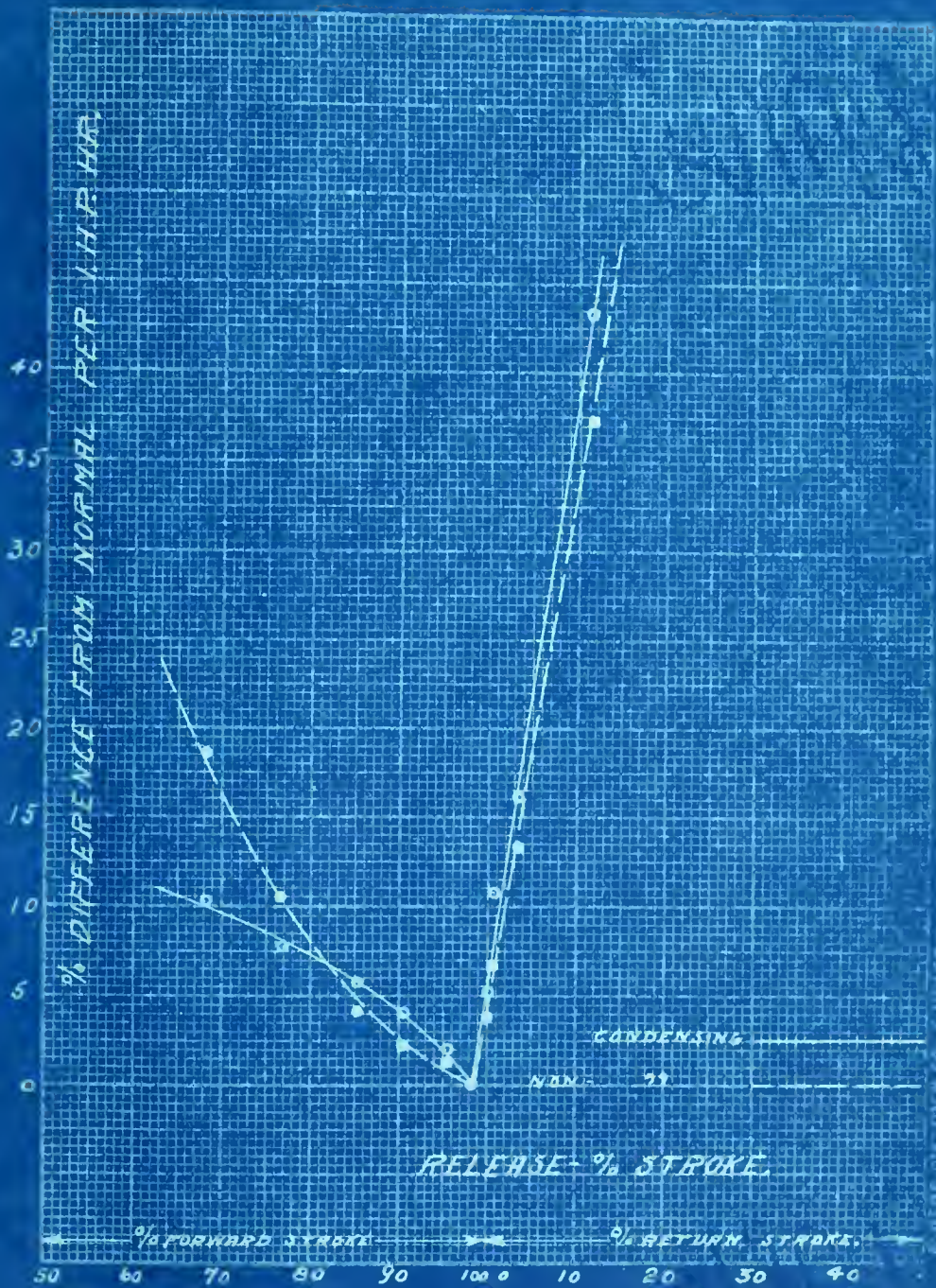
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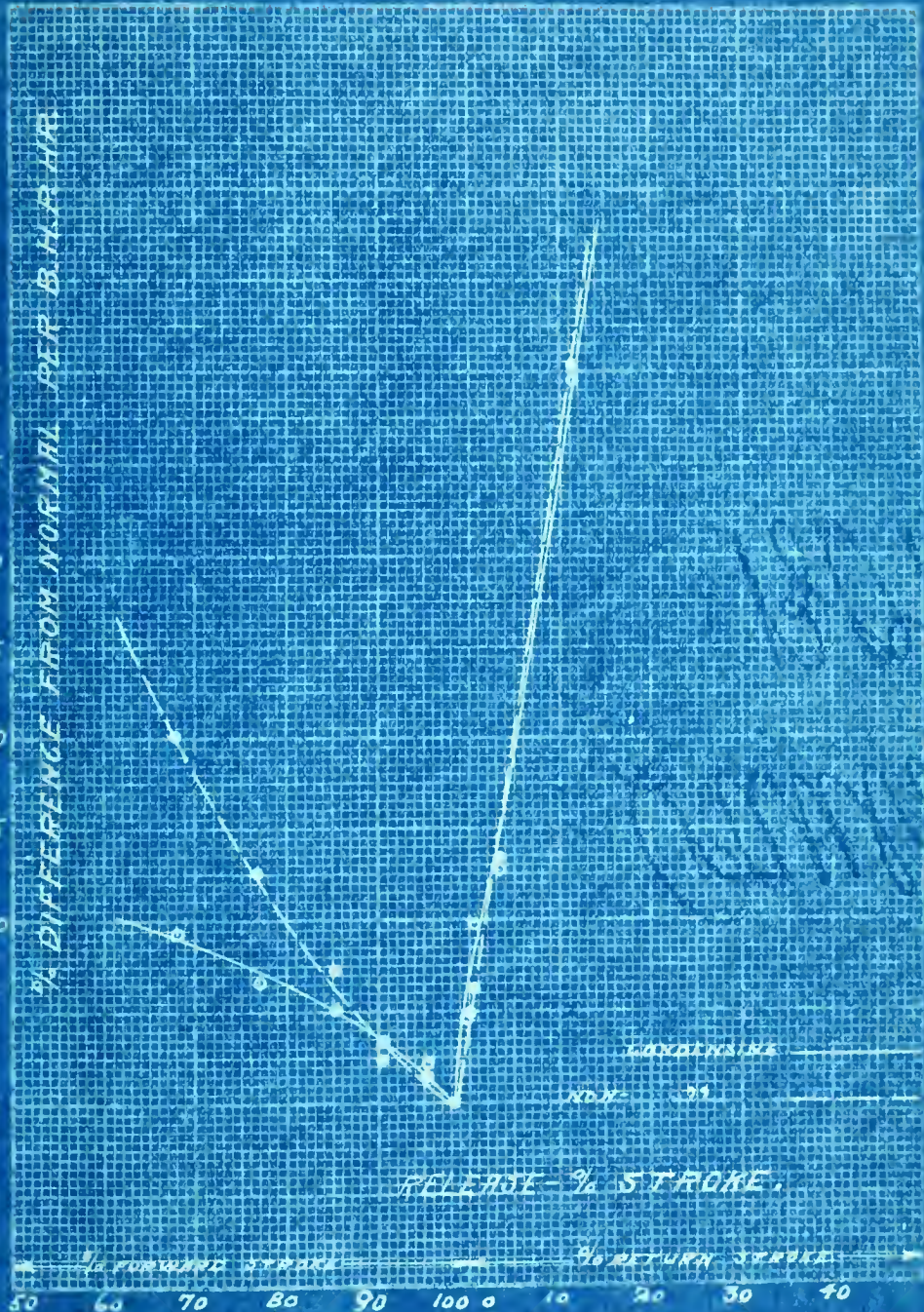
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HEMISPHERE 2 STROKE

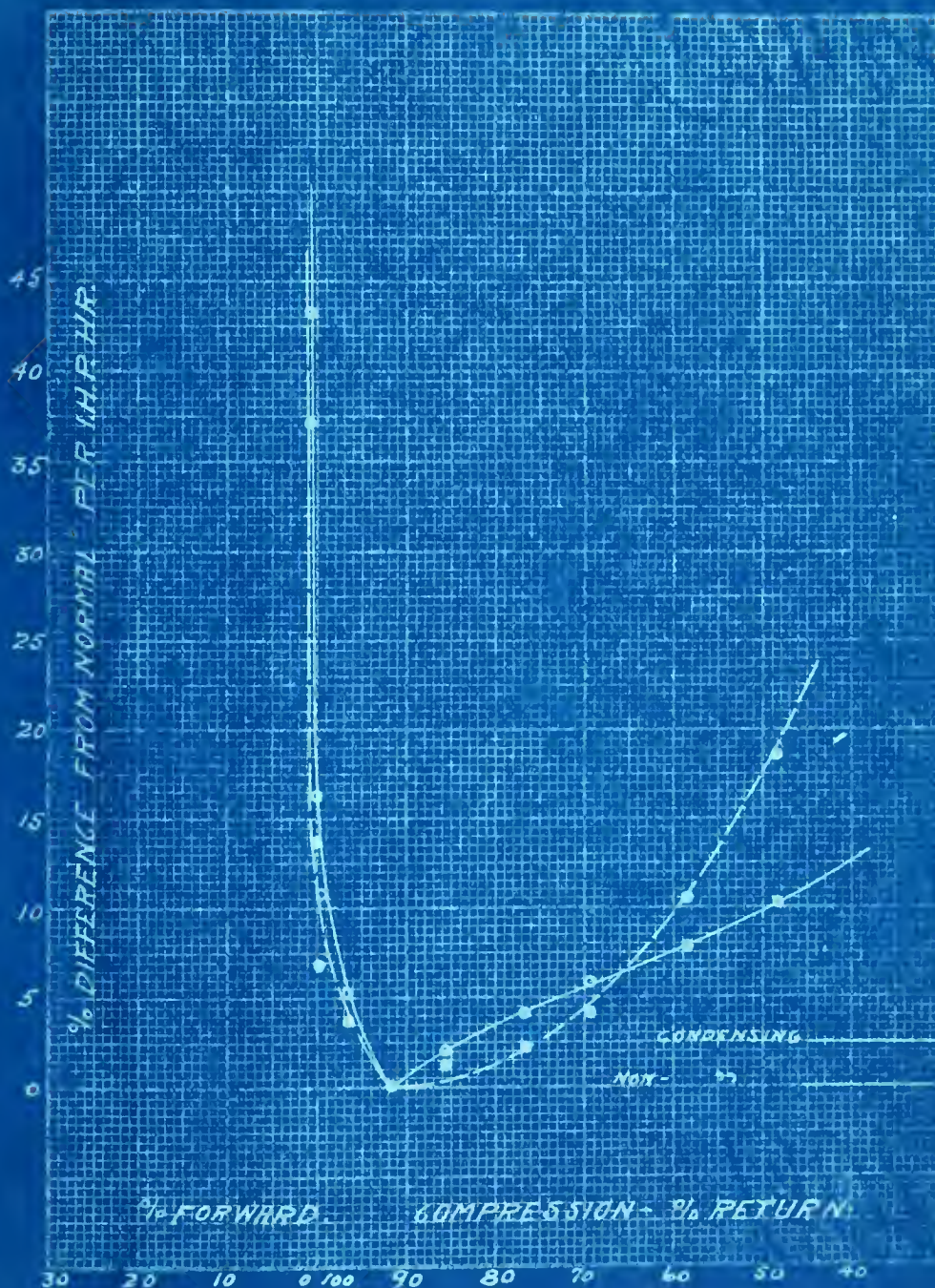
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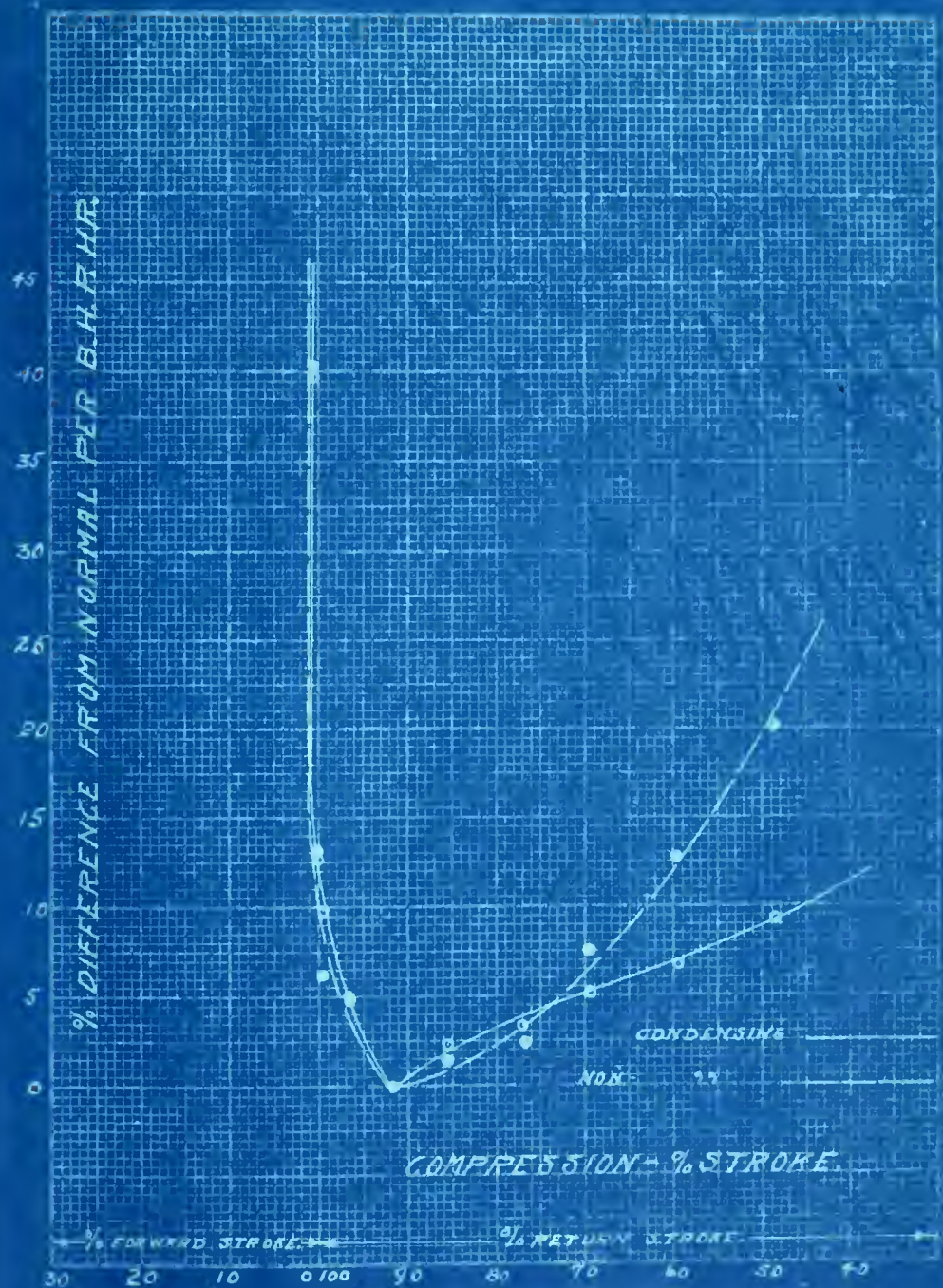
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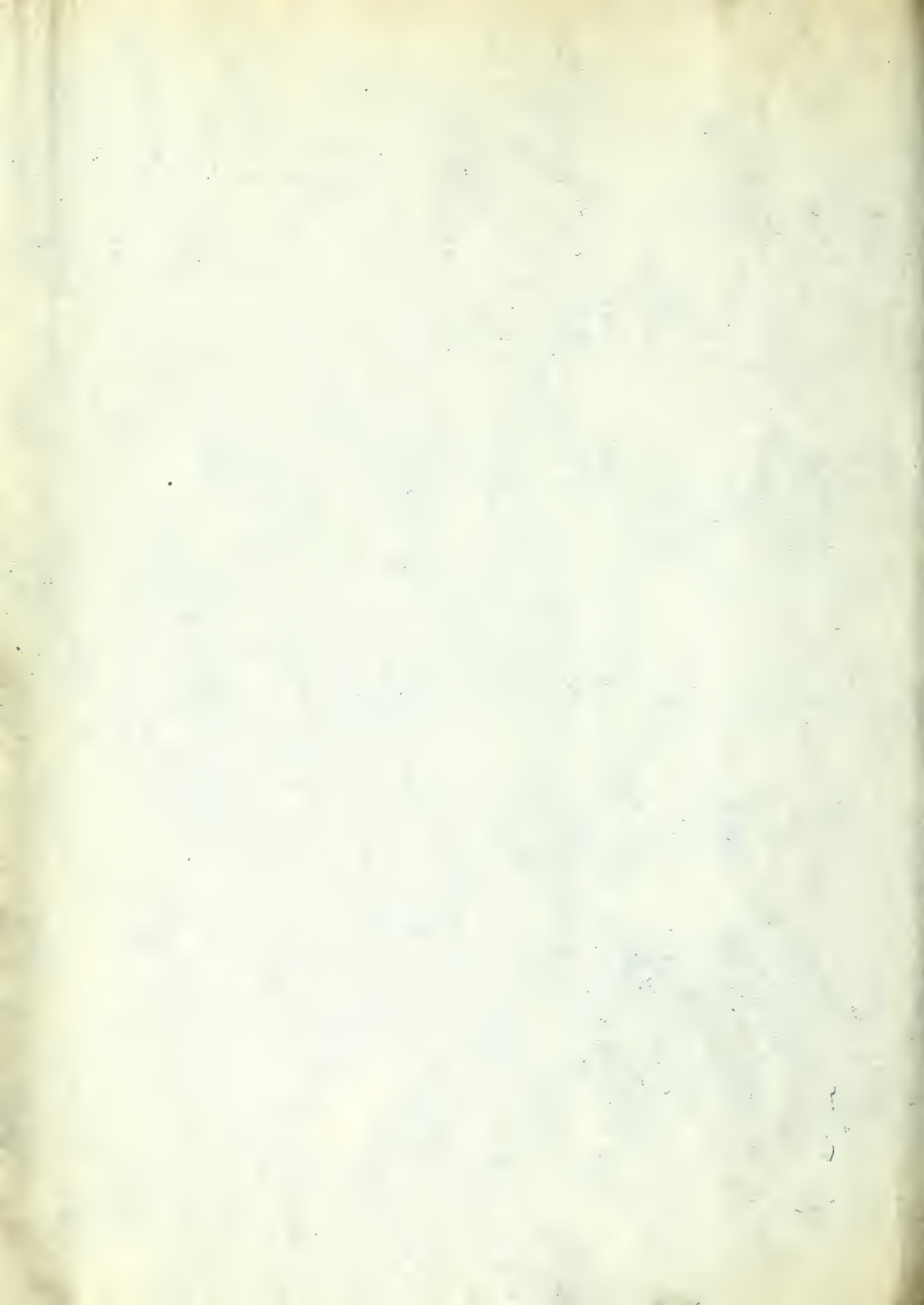






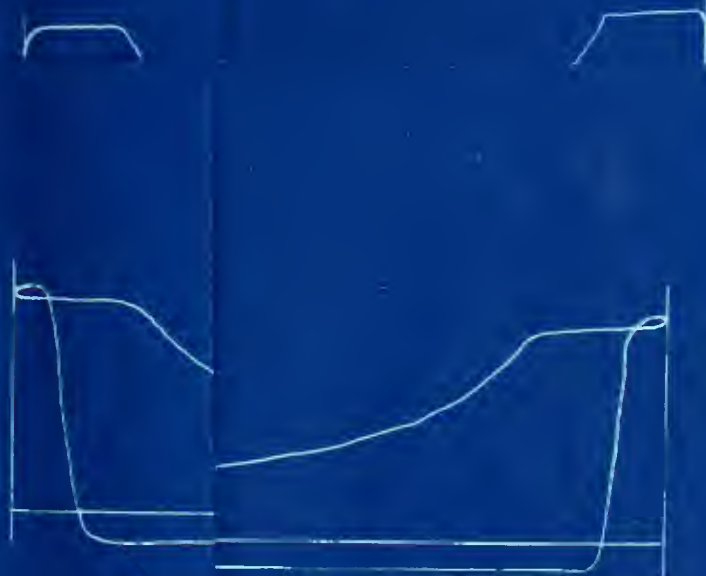






SETTING

NE.



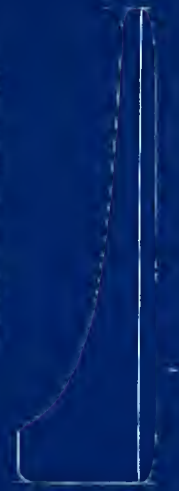


INDICATOR CARDS SHOWING CHANGES OF VALVE SETTING OF AN ALLIS-CHALMERS 9"x24" CORLISS ENGINE.

CONDENSING

HEAD END

SCALE OF SPRING 30.6#



CRANK END

SCALE OF SPRING 33#



CARD NO.	ADMISSION, % STROKE AVERAGE OF H.C. & C.E.	AREA AVERAGE OF H.C. & C.E.	R.P.M.
1	99.5 R	2.83	2.66
3	98.5 R	2.75	2.69
5	95.2 R	2.72	2.57
7	91.2 R	2.70	2.65
			94.8
			93.8
			93.1
			91.0

LENGTH OF CARDS = 4 1/8"

SETTING

E

88#



3

[Faint, illegible handwritten notes or sketches on the right side of the page.]



INDICATOR CARDS SHOWING CHANGES OF VALVE SETTING OF AN ALLIS-CHALMERS 9"x24" CORLISS ENGINE

NON-CONDENSING.

HEAD END

SCALE OF SPRING 90.4#



CRANK END

SCALE OF SPRING 80#

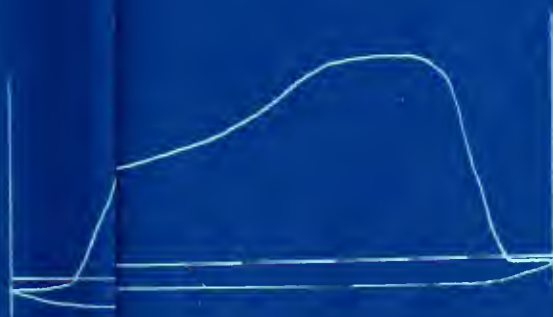


CARD NO	ADMISSION AVERAGE OF H.E. & C.E.	% STROKE OF H.E. & C.E.	H.E.	AREA C.E.	R.P.M.
2	99.5	R	2.70	2.57	93.7
4	98.5	R	2.67	2.55	93.2
6	95.2	R	2.70	2.56	92.8
8	91.2	R	2.38	2.43	90.6

LENGTH OF CARDS 4.6"

SETTING

E



3

INDICATOR CARDS SHOWING CHANGES OF VALVE SETTING
OF AN
ALLIS-CHALMERS 9"x24" CORLISS ENGINE
CONDENSING.



CARD No	ADMISSION AVERAGE	% STROKE OF H.E. & C.E.	AREA H.E.	C.E.	R.P.M.
1	99.5	R.	2.83	2.66	94.8
9		.5 F.	2.77	2.77	94.9
11		1.8 F.	2.61	2.75	94.9
13		6.1 F.	2.53	2.85	94.7

TTING

F



INDICATOR CARDS SHOWING CHANGES OF VALVE SETTING OF 4IN ALLIS-CHALMERS 9"X24" CORLISS ENGINE

NON-CONDENSING.

HEAD END

SCALE OF SPRING 90.4#



2

CRANK END

SCALE OF SPRING 80#



2



10



10



12



12

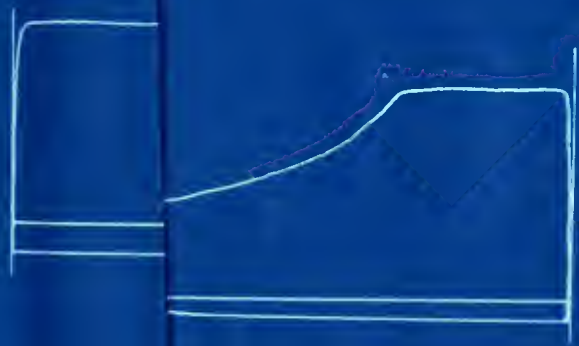
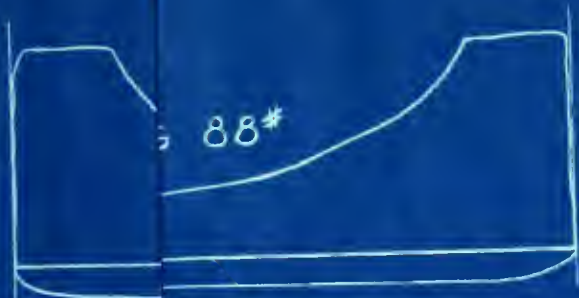


14



14

CARD NO	ADMISSION % STROKE AVERAGE OF H.E. & C.E.	AREAS		R.P.M.
		H.E.	C.E.	
2	99.5 R	2.70	2.57	93.7
10	0.5 F	2.70	2.63	93.3
12	1.8 F	2.60	2.69	93.5
14	6.1 F	2.56	2.74	93.9



INDICATOR CARDS SHOWING CHANGES OF VALVE SETTING

OF AN

ALLIS-CHALMERS 9"x24" CORLISS ENGINE

HEAD END

SCALE OF SETTING 20.4"

CONDENSING.

CRANK END

SCALE OF SETTING 28.8"



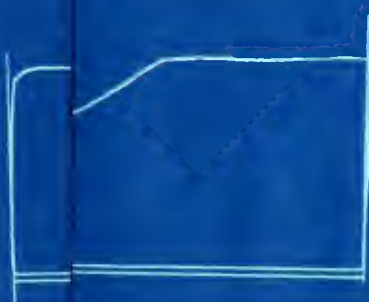
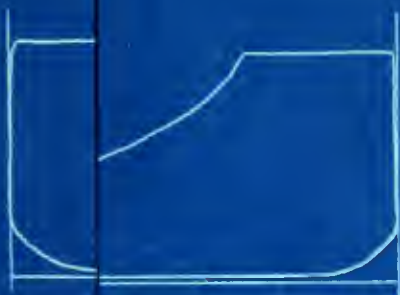
CARD NO	EVENTS	% STROKE	AVERAGE OF H.E. & C.E.	RELEASE	AREA	AVERAGE OF H.E. & C.E.	R.P.M.
1	98.4 F	91.5 R	2.83	2.66	94.8		94.8
15	100.0 F	96.5 R	2.74	2.71	93.2		93.2
17	96.5 F	99.6 R	2.67	2.63	93.1		93.1
19	3.15 R	100.0 R	2.70	2.62	93.2		93.2
21	11.3 R	0.54 F	2.73	2.62	92.5		92.5

21

21

2000-2000

NG



INDICATOR CARDS SHOWING CHANGES OF VALVE SETTING OF AN

ALLIS-CHALMERS 9" x 24" CORLISS ENGINE

HEAD END, NON-CONDENSING.

SCALE OF SPRING 20.4#



2



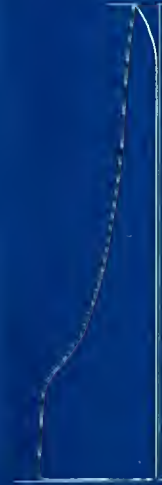
2



16



16



12



12



20



20



22



22

CARD NO.	EVENTS, % STROKE.	AREA	R.P.M.
	AVERAGE OF H.E. & C.E. RELEASE	AVERAGE OF H.E. & C.E. COMPRESSION	
2	98.4 F.	2.7 R.	93.7
16	100. F.	2.67 R.	92.4
20	99.5 R.	2.66 R.	92.5
22	99.15 R.	2.68 R.	92.2
	11.3 R.	2.75 R.	91.5

ING



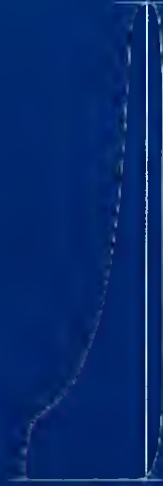
HEAD END
SCALE OF SPR. OF SPRING 88#
LENGTH OF C

INDICATOR CARDS SHOWING CHANGES OF VALVE SETTING

OF AN

ALLIS-CHALMERS 9"x24" CORLISS ENGINE

CONDENSING.



CARD NO	EVENTS, % STROKE		AVERAGE OF H.E. & C.C. IN		AREAS		R.P.M.
	RELEASE	COMPRESSION	AVERAGE OF H.E. & C.C. IN	AVERAGE OF H.E. & C.C. IN	AVERAGE OF H.E. & C.C. IN	AVERAGE OF H.E. & C.C. IN	
1	98.4 F	91.5 R	2.83	2.66	2.66	2.66	94.8
23	95.2 F	85.5 R	2.80	2.71	2.71	2.71	93.9
25	90.5 F	76.7 R	2.79	2.67	2.67	2.67	93.3
27	85.3 F	69.2 R	2.76	2.69	2.69	2.69	93.9
29	76.9 F	58.7 R	2.70	2.65	2.65	2.65	93.3
31	68.0 F	48.5 R	2.82	2.62	2.62	2.62	93.1

31

HEAD END

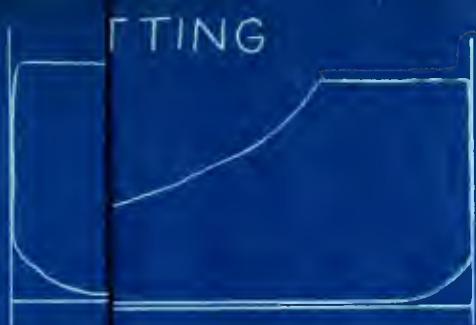
SCALE OF SPRING 100.4"

LENGTH OF CARDS 14.8"

31

CRANK END

SCALE OF SPRING 88.8"



HEAD
SCALE OF $\frac{1}{2}$ INK END
LENGTH OF SPRING 88#

INDICATOR CARDS SHOWING CHANGES OF VALVE SETTING
OF AN
ALLIS-CHALMERS 9"x24" CORLISS ENGINE
NON-CONDENSING.



2



2



24



24



26



26



28



28



30



30



32



32

CARD NO	EVENTS AVERAGE OF H.E. & C.E. RELEASE	% STROKE COMPRESSION	AREAS AVERAGE OF H.E. & C.E.	R.P.M.
2	98.4 F.	91.5 R.	2.70	2.57
24	95.2 F.	85.5 R.	2.63	2.65
26	90.5 F.	76.7	2.63	2.65
28	85.3 F.	69.2	2.70	2.69
30	76.9 F.	58.7	2.70	2.66
32	68.0 F.	48.5	2.64	2.70

HEAD END
SCALE OF SPRING 90 LBS.
LENGTH OF CARDS 4.5"

CRANK END
SCALE OF SPRING 84 LBS.



